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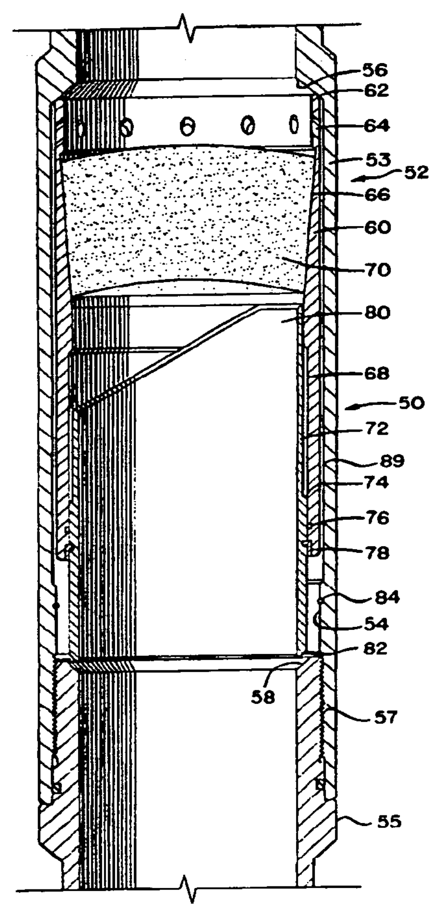
(54) **Temporary plug system for well conduits.**

(57) A method and apparatus for temporarily closing a subterranean conduit wherein a tubular housing (52) is disposed in the well, a temporary plug (70) is positioned in the housing to block fluid flow therethrough, mechanical fracturing means (72) is provided for breaking the plug (70) ; and the plug is formed at least partially of material dissolvable in the well fluid.

FIG. 2A



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prised of a salt and sand mixture which is highly resistant to fluid compressive forces but is subject to destruction under non-uniform shear forces proximate the radial edge and tensile forces at any location. The plug is preferably encased within a plug sleeve. The sleeve is then encased within a plug housing which may be disposed within the well bore. In an exemplary embodiment, the sleeve is associated with the housing so that fluid may be displaced about the plug sleeve as the housing is disposed into the well bore. In this capacity, the plug allows the well fluids to pass therethrough and fill the tubing above the plug during disposal into the well. This prevents the tubing from having to be filled from the surface to balance the hydrostatic pressures inside and outside the tubing. When the plug has reached the desired location within the wellbore, the plug sleeve is positioned within the housing so that fluid flow is blocked. This is considered to be a "check" position because the plug is blocking fluid flow in one direction (downward) in this position while it would permit flow in the other direction (upward).

An annular shear member presenting a point stress portion is contained within the plug sleeve and detachably connected thereto. When required, the shear member is released from the surrounding plug sleeve and the point stress portion forced against the radial edge plug to substantially destroy the plug structure. The plug material is substantially dissolvable within the well bore fluids to permit re-establishment of fluid flow therethrough and operations within the well bore shortly thereafter.

An apparatus commonly referred to as a plug assembly for temporarily closing a subterranean fluid conducting conduit which may include well casing, tubing string, or conduits within the downhole equipment is illustrated, disclosed and claimed herein. The plug assembly includes a tubular housing disposed within the fluid of a subterranean well. There is a temporary plug positioned within the housing for blocking fluid passage through that housing. Also positioned within the housing is a mechanical fracturing means for breaking the temporary plug so that fluid flow through the housing is permitted. The temporary plug is constructed at least partially from material that is dissolvable in the well fluid. The dissolvable portion of the temporary plug includes an aggregate and binder that are solidified into a substantially rigid frangible member that is the plug body. Because the binder dissolves in the well fluid, the individual pieces of aggregate are released one from the other. By including the aggregate, the time required to dissolve the binding material is hastened because the aggregate falls away from the binder thereby exposing increased amounts of surface area of the binder to the dissolving well fluids. The size of the aggregate is such that each particle is sufficiently small so that it will not impede other operations performed within the well after the plug deteriorates. It is contemplated that the aggregate may also be dissolvable in the well fluids. The speed with which the aggregate dissolves in the well fluid would, however, differ from the time it take the binder to dissolve.

In an exemplary embodiment, the aggregate is sand particles and the binder is salt. To assure that the sand particles do not foul other operations, it has been found to be advantageous, but not critical, to employ sand particles having a diameter of about 1 millimeter.

In one preferred embodiment, the temporary plug is at least partially contained within a dissolving resistant encasement composed of substantially pure binder. A means for piercing the encasement to allow the well fluid access to the interior of said temporary plug may be provided.

A method for utilizing the above described temporary plug will include installing a temporary frangible plug within a housing located within a fluid conducting conduit and then disposing that housing into a well so that the plug is submerged in well fluid. The temporary plug is then fractured so that it breaks into pieces that are unsupportable within the housing and subsequently permits fluid flow through the housing. The plug is then dissolved into particles small enough that will not foul future operations within the well.

In another preferred embodiment, the temporary plug has an interior core of unbound aggregate contained within a flexible membrane. The aggregate is vacuum packed within the membrane so that the temporary plug is substantially rigid while the vacuum is maintained within the membrane. To remove the temporary plug, a means for piercing said membrane is provided that opens an avenue for allowing the well fluid access to the interior of the temporary plug. A corresponding method of utilizing this embodiment includes installing the temporary plug within the housing that is located within a fluid conducting conduit. The housing is then disposed into a fluid filled well so that the plug is submerged. The membrane is then pierced so that the vacuum pressure (differential across the membrane) is balanced to allow the previously substantially rigid plug to collapse and become unsupportable within the housing. As a result, fluid flow is similarly permitted through the housing. After collapse, the loose aggregate is released from the membrane and removed away from the housing by the well fluid.

Still another embodiment has a temporary plug supported within a housing at a periphery of the plug. The plug is substantially spherically dome shaped. Due to this shape, the forces experienced in the plug are almost exclusively compressive in nature. This may be contrasted with known frangible disks which are flat and vulnerable to breakage because of the tensile and shear stresses induced during operation. In a flat frangible disk, great tensile forces may be ex-

that to which the arc of convex surface 11 corresponds. Surface 13 is preferably angled outwardly in a conical shape. It should be appreciated, however, that the dimensions of the plug 10 are governed by the distance it must span to plug a particular conduit, and therefore are variable.

The integrity of the salt and sand plug 10 just described may be improved by the application of a thin protective fluid impermeable coating 15, such as epoxy, upon surfaces 11 and 12 to seal the plug surface against the well fluid. In addition, portions of the exterior of the plug 10 may be encased in a flexible sheath or encasement 17 for protection against the well bore fluids. Neoprene rubber or other soft rubbers are suitable for constructing the encasement 17.

Alternatively, the plug material within the encasement 17 may be only sand which is vacuum packed therein. The vacuum pressure within the encasement 17, having a magnitude of approximately one atmosphere, will maintain the sand grains in dense engagement with each other to prevent relative motion therebetween. It should be understood that the relative pressure upon the encased material will increase as the plug 10 is disposed further into the well due to hydrostatic pressure. Therefore, during operation, the vacuum pressure applied to the aggregate will be equal to the hydrostatic pressure, plus one atmosphere. When it is desired to remove such a vacuum packed plug 10 from a conduit, the encasement 17 is punctured or otherwise ruptured causing the contained sand to be liberated and the encasement to collapse. It is also possible that the sheath or encasement 17 will break into several pieces. Therefore, the sheath 17 should be thin enough so that resulting pieces do not present impedances to tools disposed within the well bore following destruction of the plug. Still further, the encasement 17 may be constructed from a material that will eventually dissolve in the well fluids, but not within the expected service time of the plug 10.

Referring now to FIG. 1B, an alternative embodiment of a plug 20 is shown which is shaped substantially the same as plug 10. Plug 20 contains a central portion 21 which may be comprised of a sand/salt mixture as previously described. An outer crust 22 is formed around the central portion 21. FIG. 1C illustrates a variation on plug 20 in which caps 27 and 28 are constructed similarly to the crust 22. The crust 22 may be comprised of substantially 100% binder which is compressed and heated to be formed integrally with the central portion 21 of the plug 20. In an exemplary embodiment, salt has been utilized as the crust 22. Testing has shown that plug material formed substantially of all salt is more resistant to compressive forces and degradation from well bore fluids than plug material of a salt/sand mixture. Therefore, a crusted combination as illustrated provides a stronger plug that initially retains its rigid form but subsequently breaks down quickly once the crust erodes allowing well fluid into the central portion. During construction of the plug 20, the thickness of the crust 22 will be governed by the desired time period before the soluble crust is sufficiently dissolved to expose a portion of the central portion 21, following which destruction of the plug occurs rapidly.

Turning now to FIG. 2A, an exemplary plug assembly 50 is shown which includes an outer plug housing 52 which is substantially tubular in shape and adapted to be connected in a tubing string (conduit) disposed within a well bore in which a temporary plug is desired. The housing 52 includes an upper section 53 threadedly connected at joint 57 to a lower section 55. Upper section 53 has a radially enlarged bore section 54 having a downwardly facing, inward frusto-conical shoulder 56 and the upper terminal end of lower section 55 forms an upwardly facing, frusto-conical sealing shoulder 58. Upwardly facing sealing shoulder 58 is preferably angled inwardly at an approximate angle of 45°.

Within the radially enlarged bore section 54 is slidably disposed a plug sleeve 60 having an upper longitudinal end 62 adapted to contact the upper inwardly disposed annular shoulder 56 of the housing 52. Fluid flow ports 64 are disposed about the circumference of the sleeve 60 proximate upper end 62. Sleeve 60 also forms a tapered conical section 66 which is downwardly, inwardly tapered and disposed below the flow ports 64. A radially expanded section 68 is disposed below the conical section 66 and forms an annular bearing portion 69 between sections 66, 68. Downward shoulder 75 is disposed about the interior circumference of sleeve 60.

Within the tapered section 66 of sleeve 60 is disposed a frangible plug 70 which may be of any one of the types described or depicted with respect to FIG. 1A-1C. The plug 70 is preferably tightly received within the conical section 66. In one preferred embodiment, the plug 70 may be formed and prestressed within the tapered section to afford it greater strength against liquid compression forces while disposed within a well bore. Alternatively, the plug may be formed separately and pressed and bonded into the sleeve with a suitable sealing glue compound, such as rubber cement or the like. In any event, the interior central portion of the plug will be shielded from the well fluid.

An annular shear member 72 is disposed within the sleeve 60 and features an upper reduced diameter portion 61 forming an outwardly facing annular shoulder 74 which is received within the radially expanded section 68 of the sleeve 60. The upper terminal end of member 72 is supported by bearing portion 69. One or more elastomeric seals 76 may be used to seal the connection between shear member 72 and the sleeve 60. A shear ring 78 detachably connects the sleeve 60 to the shear member 72. Shear member

If it is desired to destroy plug 102, a pressure must be applied into flow bore 109 which exceeds the shear value of the shear wire 134. For this reason, the value of the shear wire or other shear mechanism must be set in excess of those operating pressures under which plug 102 is designed to resist. Increased pressure downward through flow bore 109 will act across the surfaces of plug 102 and piston 114, urging them downwardly along with outer and inner support members 120 and 122 and sleeve 130. When shear wire 134 is sheared, inner sleeve 130 will move downward with respect to ring 132 and shear member 136. As this occurs, ring 132 blocks downward movement of outer support member 120 but not inner support member 122. The radial support of the edges of plug 102 at shoulders 126 will now be removed and plug 102 will be supported solely by the protuberances 128 of the outer support member 120. This creates non-uniform shear forces proximate the edges of the plug 102. The lack of uniform support for the plug 102 will allow the pressure within the flow bore 109 to destroy plug 102 thereby acting as the plug rupture mechanism. Ideally, the plug 102 breaks into a number of small pieces as a result of the stress patterns. Once ruptured, the pieces of plug 102 should be sufficiently small so as not to foul other operations subsequently performed within the well. As a result, the plug 102 is substantially eliminated from the wellbore.

In a variation of this embodiment, it is contemplated that a water soluble metal may be used to construct the plug 102. After physical destruction of the metal plug, the well bore fluids dissolve the plug fragments within a short time thereafter.

A further exemplary embodiment of the present invention is shown in Figures 4 and 5. In this embodiment, the plug rupture mechanism provides selective well fluid access to portions of the radial edge of the plug 70 which are readily degradable by fluid contact. It is noted that plugs which are suitable for use in plug assemblies of this type are those constructed similar to or shown in Figure 1A-C.

Figures 4 and 5 illustrate cross-sectional views of an exemplary plug assembly 150. To aid in illustrating the operation of the plug assembly 150, the figures present juxtaposed halves of the tool in different stages of operation. The right half of Figure 4 illustrates the assembly 150 as it would appear while being disposed downwardly within the well bore and permitting fluid flow upwardly around the plug 70. The left half of Figure 4 shows the plug assembly 150 set for fluid flow blockage. The right half of Figure 5 shows the plug assembly 150 after initial plug rupture. The left half of Figure 5 illustrates the configuration of the assembly 150 following substantial destruction of the plug 70.

The assembly 150 includes an upper adaptor 152 with upper threads or other connector means 154 which permit the assembly 150 to be incorporated within a conduit. Upper adaptor 152 is connected at thread 156 to plug housing 158. Plug housing 158 includes lower adaptor threads 160 for connection with other portions of a conduit. A central portion of housing 158 includes sleeve bore 162 having inner upward facing shoulders 164, 166 and 167.

Above sleeve bore 162 is radially expanded fluid flow bore 168 which presents an annular upward facing shoulder 170. Annular ring 172 is disposed proximate fluid flow bore 168 within the housing 158 and features an annular lower shoulder 174 which is adapted to be generally complimentary to shoulder 170. It is preferred that shoulders 170 and 174 do not form a seal, but, when engaged, will permit fluid flow therebetween. Ring 172 features a number of lateral ports 176 about its periphery.

Sleeve bore 162 contains a sleeve 178 which is slideably received therein. Sleeve 178 presents an outwardly tapered plug support section 180 with an upper ring contacting portion 182. The outer radial surface of sleeve 178 presents a downwardly facing shoulder 184. The sleeve also presents a lower edge 186 which is complimentary to seat 188 of sleeve support member 190. Sleeve support member 190 is shear pinned at 192 to plug housing 158 and features lower edge 191.

During disposal within a well bore, assembly 150 permits fluid flow around the plug sleeve 178 in a manner similar to that described with respect to previous embodiments and as shown in the right side of Figure 4.

When disposed within a well bore for blockage of fluid flow therethrough as illustrated in the left half of Figure 4, plug sleeve 178 is moved downwardly within bore 162 until lower edge 186 contacts seat 188 to form a seal against fluid flow therethrough. In this portion, little or no fluid flow is permitted between shoulder 174 and ring contacting portion 182 toward portions of plug 70.

Upon application of increased pressure within the well bore 151, sleeve 178 is shifted downward as shown in the right half of Figure 5 until downward facing shoulder 184 of the sleeve 178 contacts shoulder 164. Upward facing shoulder 166 may also act to limit downward movement of sleeve support member 190 and edge 191 will ultimately be limited from excessive downward movement by shoulder 167. In this downward position, pressurized fluid within well bore 151 passes through ports 176 outward into radially enlarged fluid flow bore 168 and between shoulders 170 and 174. Due to the separation of ring contacting portion 182 and shoulder 174, fluid is permitted to contact plug 70 proximate its upper radial edge to begin dissolution of the plug 70 as previously described. After a period of time, plug 70 dissolves as shown in the left half of the Figure 5.

While the invention has been described with respect to preferred embodiments, modifications there-

FIG. 1A

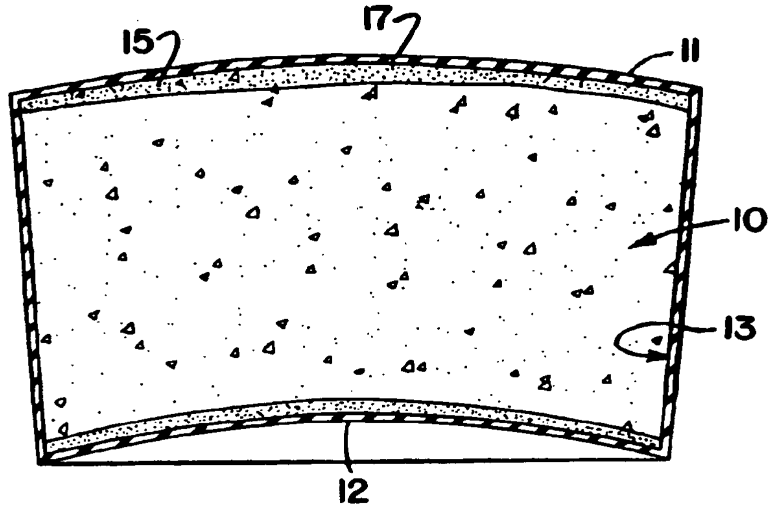


FIG. 1B

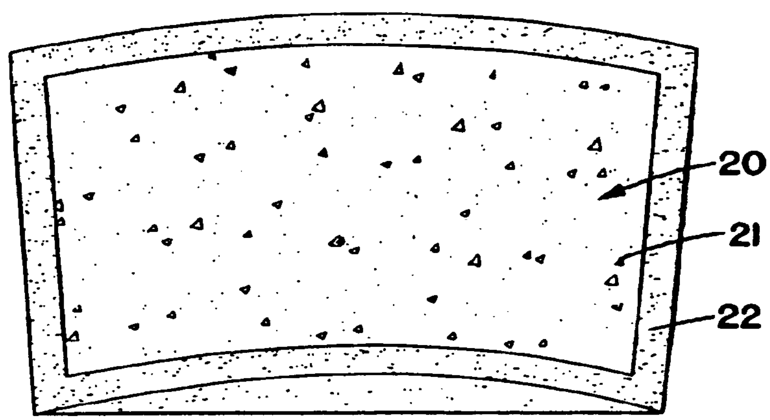
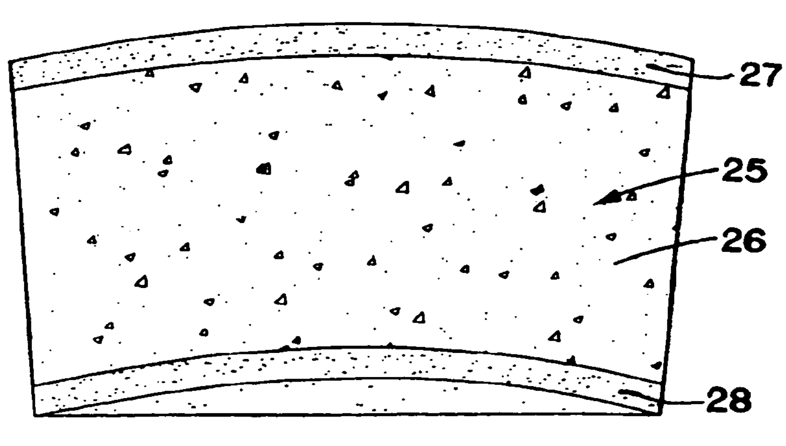


FIG. 1C



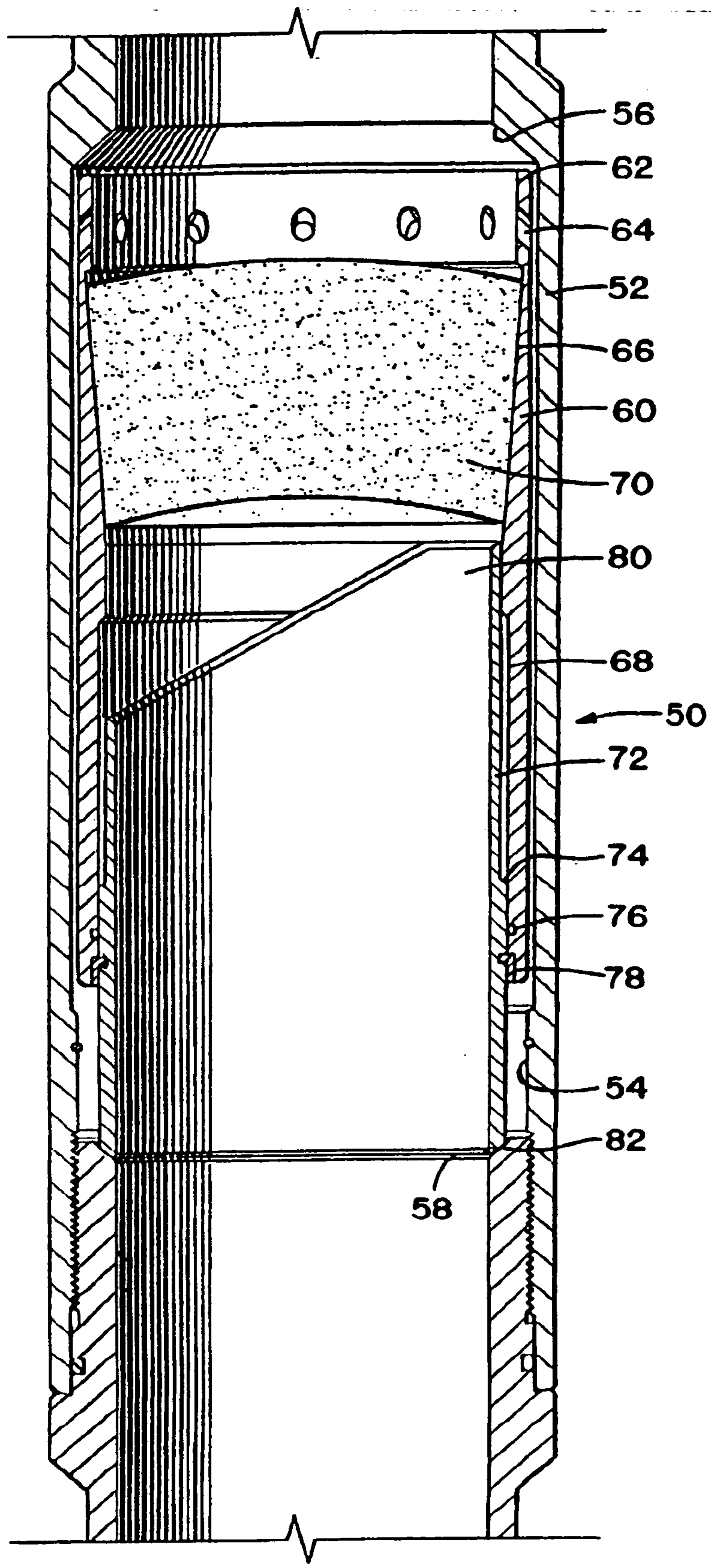


FIG. 2B

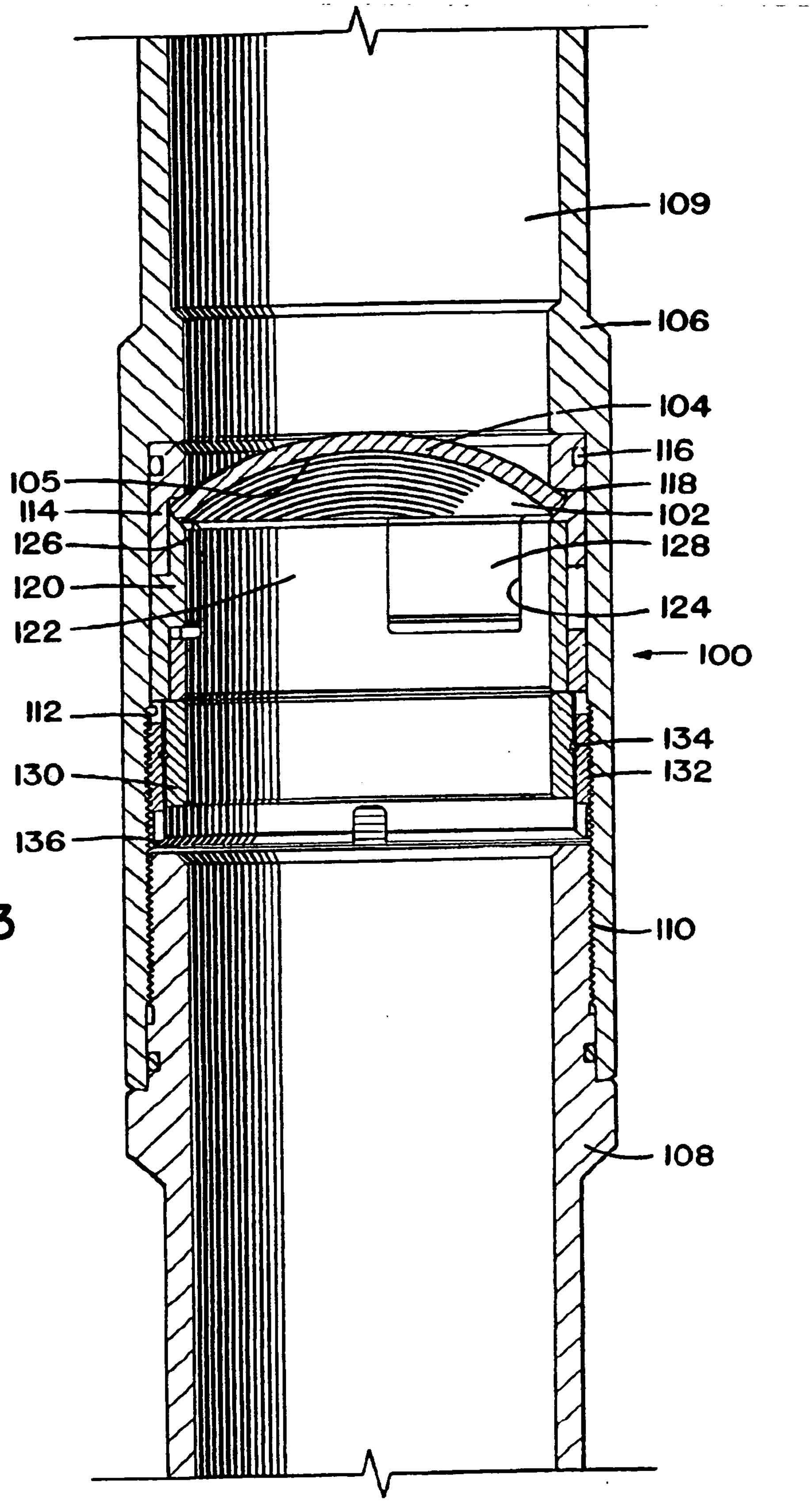

109
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FIG. 3

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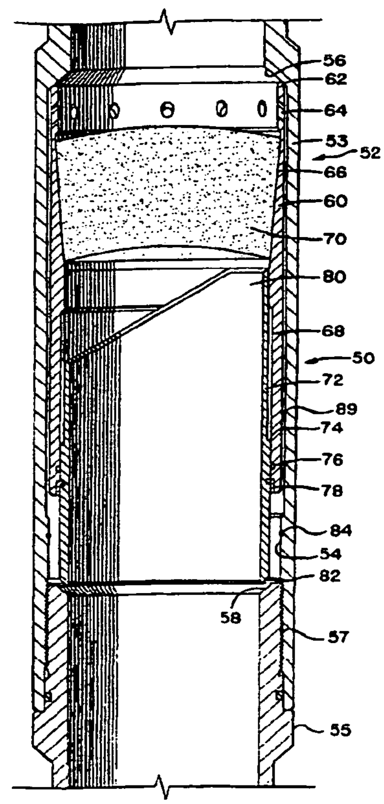

FIG. 2A

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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 3024

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 188 182 A (ECHOLS III RALPH H ET AL) * abstract * * column 2, line 27 - line 56 * * column 6, line 42 - line 64 * * column 9, line 10 - line 21 * * claim 29 * ---	1,2,9,10	
A	US 4 813 481 A (SPROUL RICHARD M ET AL) * abstract * * figures 3,7 * * column 1, line 11 - line 40 * * column 6, line 9 - line 40 * * claims 6,8,9 * ---	1,4,9,10	
A	US 4 919 989 A (COLANGELO ROBERT V) * abstract * * figure 5 * * column 3, line 3 - line 53 * ---	1,5,10	
A	US 4 160 484 A (WATKINS FRED E) * abstract * * claims 1-6 * ---	1,10	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 4 541 484 A (SALERNI JOHN V ET AL) * abstract * * figure 3B * * claim 1 * ---	1	
A	US 4 374 543 A (RICHARDSON CHARLES N) * abstract * ---	1	
A	US 4 433 702 A (JOHN R. BAKER) * abstract * * claim 1 * ---	1	
A	US 4 721 159 A (OHKOCHI KATSUTOSHI ET AL) * abstract * --- -/--	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	25 April 1997	Schaeffler, C

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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E : earlier patent document, but published on, or after the filing date
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L : document cited for other reasons

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